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THE RECENT INVESTIGATIONS OF THE GULF STREAM BY THE U. S. COAST AND GEODETIC STEAMER "BLAKE."

BY

COMMANDER JOHN R. BARTLETT, U. S. NAVY, ASSISTANT IN THE COAST AND GEODETIC SURVEY.

I consider it a great honor to be connected in any way with the investigation of this great river of the ocean, and it will give me pleasure to lay before the Society any new facts that I have obtained, under the direction of Mr. Patterson, the present Superintendent of the Coast and Geodetic Survey.

To the United States Coast Survey, first organized by Mr. Hassler, and especially to the systematic examination instituted by Professor Bache, are we indebted for most of our knowledge of the Gulf Stream, a knowledge which has been of inestimable value to the mariner.

The investigations begun by Dr. Franklin, and pursued by his descendant Professor Bache, have been continued by Prof. Peirce and Mr. Patterson, but by none with more earnestness than by the present Superintendent, who has the advantage of the more modern and improved instruments. Mr. Patterson kindly gave me per mission to use the data obtained by the steamer *Blake*, in preparing my paper. The Coast Survey deals only in facts, and the superintendent told me that any theories advanced, must be my own. I shall, however, present you the facts and leave you to draw the conclusions.

The facts obtained by the steamer *Blake*, regard: depths, temperatures from surface to bottom, character of bottom, specimens of water for analysis from surface to bottom, surface and under currents, and animal life from surface to bottom, especially at the latter.

Many of my hearers have probably read more than I on the subject of the Gulf Stream, and some have listened to papers by our most learned and scientific men in relation to its origin, course and temperature. A very interesting article appeared in the *Galaxy* from the pen of your own Dr. Hayes. Every one has read Lieutenant Maury's entertaining chapter on the Gulf Stream, in his "Physical Geography of the Sea;" but his theory of its source is generally disputed. He says the brine of the ocean is the lye of the earth; and that from it the sea derives dynamical power and its currents their main strength. He traces all ocean currents to differences in specific gravity.

It is its source of which I wish first to speak, in order to lead up to the point at which I hope to be able to give some new data. I will not enter into a lengthened discussion, but I wish to assume that the equatorial current is the source of the Gulf Stream, and I only quote a few words from the best authorities on the subject.

Sir John Herschel says: "The dynamics of the Gulf Stream have of late, in the work of Lieutenant Maury, been made the subject of much (we cannot but think misplaced) wonder, as if there could be any possible ground for doubting that it owes its origin entirely to the trade winds."

Sir C. Wyville Thomson has some very interesting remarks on the Gulf Stream in his recent work, "The Depths of the Sea," and comes to the conclusion that it is the reflux of the great equatorial current.

Humboldt attributes the origin of this current to the trade winds, and lays the first impulse and origin of the Gulf Stream south of the Cape of Good Hope.

There is no doubt about the equatorial current. Columbus wrote in his journal: "I regard it as proved that the waters of the sea move from east to west as do the heavens."

I would liken this great equatorial current to the heart in the human body, supplying the Gulf Stream with fluid as through the arteries, the water finding its way back naturally by the polar and colder currents or veins, to its original source. This action goes on in the Pacific as well as in our own Atlantic. The life or moving power is, as Herschel says, the trade winds, and this force is derived from the sun. Professor Bache, in his paper on the Gulf Stream, says: "The great part which the heat of the sun plays in disturbing the equilibrium of the surface of our globe is well understood. Wherever he shines upon the surface, the air resting upon it is set in motion, so that the circle of the sun's illumination, as it advances over the earth, is a circle of disturbance."

An article in the *American Cyclopedia*, based on Coast Survey reports and Professor Bache's paper, says: "The equatorial current, that volume of water moving from east to west on our globe, interrupted by continents, and sending off branches in other directions, again to reunite, may be said to commence, or, more properly, reappear on the west coast of Africa. The action of the trade winds, which blow constantly between the tropics, is the cause of this current, and, without doubt, its velocity is increased by the rotation of the earth on its axis. Flowing on both sides of the equator in longitude 30° W., its breadth is estimated at 300 miles. Here it divides, the southern branch forming the Brazil current, the remainder flowing on to supply the Gulf Stream."

It is said to flow through the Caribbean sea to the Gulf of Mexico. It will be my purpose to show its course from the time we meet it to the eastward of the Windward Islands until it enters the Gulf of Mexico at the Yucatan passage. It is said that, at times, the water flows through this passage from 27 to 50 miles in 24 hours. Near Yucatan, we found it in the month of May flowing at the rate of three miles an hour. From this point the course of the current is generally described as making the tour of the Gulf of Mexico, or following around its boundary, before passing out at the Straits of Florida. This is disputed now, with, I think, very good reason. The investigations made by the Coast Survey carry the current passing through the Yucatan passage well to the northward, where the waters are banked up by the pressure, and thus form a head or reservoir for the current, which flows from a point south of the mouth of the Mississippi direct to the Straits of Florida.

South of Tortugas, the stream flows to the eastward, gradually increasing its velocity as it moves on. Opposite Havana, where its breadth is about 70 miles, its average rate is said to be two miles an hour in the centre, decreasing on each side; northwest from Elbow Key, where its breadth is about 47 miles, the set, in the centre, is said to be northeast three miles an hour, with an increased rate toward the Florida reefs. The stream now bends to the northward, and, in the straits between Cape Florida and the Bemini Islands, its velocity is said to vary from one-half mile to even five miles an hour. This is the narrowest part of the stream, and I find it stated that its maximum temperature is 85°. The season of the year when it reaches this maximum is not given. I will speak of this part of the stream later on, and will mention the date when giving temperatures or currents observed by the *Blake.*

In November, 1878, I was ordered to report to the Secretary of the Treasury for duty on the Coast and Geodetic Survey, and was assigned by Mr. Patterson, the superintendent of that service, to the command of the steamer *Blake.* My instructions for the first season's work, after the dredging for Mr. Agassiz had been completed, were as follows:

"You will please take soundings in the passages between all the islands from Trinidad to Cuba, not already sufficiently sounded, for the purpose of determining the ridge of least depth of water traversing these passages. Temperatures from surface to a depth of 100 fathoms, and at the bottom, should be obtained as often as opportunities offer, and serial temperatures, from surface to bottom, between the islands and on each side of the shoalest ridge."

It will be seen by these instructions that it was Mr. Patterson's idea to find the amount of water which enters the Caribbean sea between the Windward Islands, and, what was more important than anything else, to observe carefully the temperature of the water at different depths, as these temperatures would give the most interesting data in reference to the circulation.

As Mr. Patterson says in his report: "The discovery by the *Challenger* of submarine lakes, whose temperatures are constant to the greatest depth with that of the ocean at the depth of their rims, rendered it more than ever imperative to determine the depth of the rims separating the waters of the Gulf of Mexico from those of the Caribbean, and its waters from those of the Atlantic, both to the eastward and westward."

As it was very important to connect the fauna of the West Indies with the Arctic fauna, and as naval officers are professionally neither naturalists nor geologists, Mr. Patterson sought the services of Mr. Alexander Agassiz, who consented to take charge of the special work, naming the localities to be dredged over, and taking care of the life obtained. Professor Agassiz joined the *Blake* with an assistant, and the first part of the season's work, until March 10th, 1879, was occupied in dredging and trawling under the lee of the Windward Islands. We met with great succees in this very interesting work; but this part belongs more especially to Professor Agassiz, who will, in due time, present a popular account of the results of his labors. As the working of the dredge and trawl was done by the officers and crew under my command, I will, if time permits, give some account of our appliances.

Besides dredging under the lee of the islands, we made a number of soundings and hauls to the southward of Grenada, enough to develop the channel between that island and Trinidad. The greatest depth was 421 fathoms in a channel 30 miles wide; temperature at bottom, 41½°. We were here the latter part of February, and found the current very strong to the westward. It is stated by a number of authorities, and published as the observation of the English surveyors, that a strong current is felt all along the Spanish Main a few miles from the coast.

In making the passage from St. Vincent to Barbadoes in the first week in March, we experienced a current of about 40 miles in 24 hours setting to the northward, and from enquiry on board English men-of-war and merchant vessels at that time in port, I found they had experienced the same northerly current. I crossed this passage again, in the latter part of March and in the middle of April, finding the same current.

Our method of finding the ridge connecting any two islands, was by running traverses, or a line of soundings begun in deep water and carried at right angles to a line drawn between the islands. The soundings would gradually shoal to a minimum and then increase, when a new line of soundings was run across the ridge at such an angle as to bring the soundings at the shoalest point about four or five miles apart. At every sounding the temperature of the surface was observed, as well as the bottom. I have spoken of the passage to the southward of Grenada. Our first sounding and temperature work was between St. Vincent and St. Lucia. A connecting ridge was found between these islands having a greatest depth of 488 fathoms, a bottom temperature of 41½°. The soundings across were 488, 370, 198, 171, 129, 164 fathoms.

It will be seen by the contour lines that the water deepened gradually to the Atlantic and quite abruptly into the Caribbean sea. Traverses were run between all the islands as far as the Virgin islands, with the following depths: Between St. Lucia and Martinique, 548 fathoms, temperature 41°; between Martinique and Dominica, 575 fathoms, temperature 41°; between Dominica and Guadaloupe, 346 fathoms, temperature 44½°; between Guadaloupe, Antigua and Nevis, 386 fathoms, temperature 45°; between Anguilla, Sombrero and Anegada, 1,100 fathoms, temperature 38° on the ridge, but this latter sounding was in a canyon, not more than two miles wide, and on each side of it were only a few hundred fathoms. Between Anegada and Sombrero, we found, outside of the ridge, a temperature of 38° at 1,346 fathoms, 37½° at 1,643 fathoms, and 36½° at 2,558 fathoms. The lowest temperature that was found inside was between St. Thomas and St. Croix, that of 38° in 2,470 fathoms. To the southward of St. Croix, inside of the islands, the temperature of all depths below 800 fathoms was 39° to 39½°, and it was only in the deep hole north of St. Croix that we found anything lower. It will be seen by the contour lines that the deep water was traced in a channel from Anegada passage to a line between St. Thomas and the west end of St. Croix. The temperature at 1,542, 1,517, and 1,508 fathoms, south of Mona passage, was only 39½°, which would seem to indicate a connecting rim from St. Croix to the northward, cutting off the cold water that was found between St. Thomas and St. Croix.

In every passage a series of temperatures, or serial, was taken to the eastward of the ridge, then directly on the ridge, and again in the Caribbean sea. The depths for a serial were: surface, 2, 10, 25, 50, 75, 100, 150, 200, 300, and so on at each hundred fathoms. The temperature at the bottom for the same depth remained constant in the same locality; by comparison, these agreed with the same depth obtained in a serial. At Barbadoes, St. Lucia and Martinique the temperatures were at 100 fathoms 56½°; 200 fms., 51°; 300 fms., 45°; 400 fms., 43°; 500 fms., 41½°; 600 fms., 40½°; 700 fms., 40°; 800 fms., 39½°.

Just north of Guadaloupe the temperatures suddenly increased. and at Monserrat were: 100 fms., 67°; 200 fms., 57°; 300 fms., 48°; 400 fms., 45°; 500 fms., 42°; 600 fms., 41°; 700 fms., 40°. There was a slight increase as we neared the Anegada passage. These temperatures remained the same to the Mona and Windward passages, and were carried through the Western Caribbean. The temperatures in the Windward passage in May were: 100 fms., 68°; 200 fms., 61°; 300 fms., 53°; 400 fms., 47°; 500 fms., 43°; 600 fms., 41°; 700 fms., 40°; 800 fms., 39½°. The temperatures between Haiti and Jamaica were not quite as high.

In February the surface was several degrees lower than in May, but the temperature at 100, 200 and 300 fathoms were the same at the Windward passage.

Between some of the islands we were five and six days in completing the development of the ridge. The trades blew almost a gale during the months of January, February and March, hence it was very tedious work ; the small vessel of only 320 tons pitching her bows under, while the greatest care had to be exercised by the officer in charge of the sounding to prevent an accident to the wire. We worked during daylight, locating the position of the soundings by bearings taken on points of the islands, at night heading to the wind and sea under just enough way to keep in our place. While at work among these islands I wrote to Mr. Patterson: "The water does not set into the Caribbean sea through the passages between the islands to any great extent. The trades bank the water against the windward side of the islands, and near their ends the current sets strong to the westward, but we did not find the strong current in mid channel."

In the passages between the Windward islands we saw large quantities of the sea or gulf-weed. In the latter part of April we had calm weather north of Guadaloupe, and I have seen this weed extend for miles in lines always pointing north. This was not owing to the wind, for at the time I speak of it was a dead calm, but seemed to be caused by the current flowing between the islands, which agrees with our observations of the direction of the current. Especially was this the case north of Guadaloupe and near St. Christopher and Saba islands. Again, in the Anegada passage I saw the same string of gulf-weed stretching in lines to the northward.

There was a great deal of gulf-weed north of St. Domingo the 1st of May, passing through the Windward passage and south of Cuba; but I saw none south of Jamaica or over the Pedro and

Rosalind banks in the same month, nor did I notice the presence of this weed in the latter locality in January, February, March and April of 1880.

I was very much puzzled over a current experienced on the passage from Kingston, Jamaica, to St. Thomas, in the latter part of December, 1879. The trades were very strong from the eastward, but we had an easterly current of nearly two knots against wind and sea as far as the Mona passage, and a knot to St. Thomas. The captain of an English telegraph steamer whom I met at St. Thomas, who had been three years in the waters in question, stated that he had always found the current setting to the eastward; and I was given the same current by a number of English men-of-war. No dates were given. It is marked on the chart that the current sets to the eastward during the full and change of the moon.

North of Guadaloupe, by observation and dead reckoning, we found the current northerly in the latter part of April; after leaving Saba island the current was N.N.W., about a mile per hour; on our way from St. Christopher to St. Thomas we had a current of one mile per hour setting to the eastward in the same month.

The temperature of the surface water from Barbadoes to the Windward passage was from 79° to 80°; in calm weather, in the daytime, it would rise as high as 81°. This was from March at Barbadoes to May in the Windward passage. In January, 1880, we found the temperature of the surface water in the old Bahama channel and at the Windward passage only 76°. This gradually increased, as we went to the westward and the season advanced, to 78°, 79° and 80° near the Caymans in March, and to 81° and even 82° in May between the Misteriosa bank and the Yucatan passage. Over the Pedro and Rosalind banks, and north of the Mosquito coast, it was 79° and 79½° in February and March.

The bottom obtained in the soundings directly on the ridges was generally coral sand and dead coral; on each side, in the deeper water, it was pteropod ooze. As I shall speak so often of this ooze, I may as well describe it now. After reaching a depth of four or five hundred fathoms, we always brought up a light brown or coffee-and-milk colored paste. This paste is formed of innumerable pteropod shells. The pteropod belongs to the division of mollusca, and is characterized by having broad fleshy wing-like appendages or organs of motion. The shell is transparent and very beautiful. This form of life lives at the surface, and when the animal dies the shell sinks to the bottom, and there decomposes and forms the paste or ooze spoken of. In sifting the ooze collected in the trawl, we found a great many whole pteropod shells.

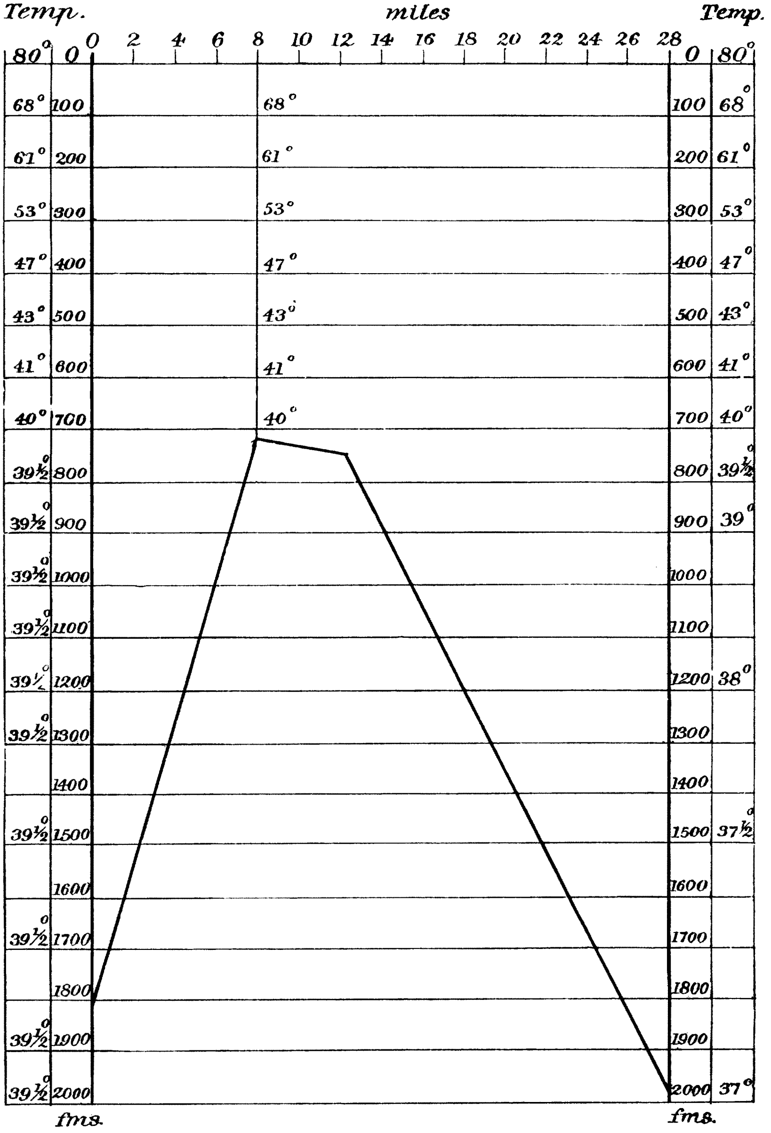
The Mona passage was thoroughly sounded, and the greatest depth was found to be only 260 fathoms; the islands of St. Domingo and Porto Rico being connected by a plateau of like character with Porto Rico.

It will be seen by the soundings from Grenada northward, that the connecting ridges have the same character of mountain and valley as the lands which they connect. Between Martinique and Guadaloupe, we found a peak in mid channel with only 40 fathoms, deepening on all sides to several hundred.

The bottom in the Mona passage was very hard, and no specimens were obtained. The surface of the connecting ridge seemed swept of everything. The wind was very strong while we were at work here, and the current west of Porto Rico set to the southward near the island, but at the west side of the passage the current set to the northward; this was in May. From the Mona passage soundings were taken every 20 miles, on the way to the Windward passage, north of St. Domingo. The depth averages over 2,000 fathoms with a bottom temperature of 36½° to 37°. There was a light easterly breeze here, and we found the current to the westward at the rate of 1½ knots per hour.

A very good profile was made of the ridge connecting Cuba with Haiti the first season, and this was verified and many new soundings were added last winter. The deepest water on the ridge was less than 800 fathoms. The temperature at 700 fathoms was 40°; below 700 fathoms, 39½°; and the same temperature was always found at all depths below 700 fathoms in the Western Caribbean by the *Blake* while under my command, and by Lieutenant-Commander Sigsbee in the same vessel in the Gulf of Mexico. The temperatures outside of the ridge at this passage were: 800 fathoms, 39°; 1,000 fathoms, 38½°; 1,200 fathoms, 38°; 1,500 fathoms, 37½°; 2,000 fathoms, 37°. Inside of the ridge the temperature was constant at 39½° from 750 fathoms to 1,900 fathoms, 10 miles inside the ridge, and to 3,000 fathoms farther on. The first season

A cross section of ridge, Windward passage.



we were not able to get any specimens on the ridge at the Windward passage with the sounding cylinder, except a few small stones The moment we crossed the immediate ridge on either side, the bottom was pteropod ooze. Last winter I made two hauls of the dredge in 700 fathoms directly on the ridge. The dredge brought up a quantity of hard coral rock or crust torn from the bottom. It had very much the appearance of old mortar, and was similar to the coral rock found on the northwestern end of Haiti, this part of the island being of coral to the very tops of the mountains. The southwestern end of the island is of volcanic formation, and is covered with luxuriant foliage, but at St. Nicholas Mole it is barren. The land, as seen from the sea, lies in terraces. Barbadoes is of similar formation in terraces to 300 feet above the sea, and all coral.

The second haul of the dredge was near Cape Maysi, still in 700 fathoms. The same bottom was found, also hundreds of shells of the "Scalpellum regium" (a kind of barnacle), which is described by Sir C. Wyville Thomson in his "Voyage of the *Challenger*." These shells were black and looked very old.

A few very small sponges and sea-urchins were brought up, but everything that could be swept away by a current was wanting. As I remarked before, all the ooze brought up, when sifted in water, was found to contain many whole pteropod shells, but my attention was particularly drawn to the fact that south of the ridge the ooze contained many more whole shells than that obtained to the northward. The current must have swept them off the ridge. While sounding between Miraporvos island and Cay Verde, in 1,400 fathoms, the sounding cylinder came up literally packed with these shells. The current in which they were suspended is here retarded by the Bahama banks, and they fall in this eddy; of course they must be falling everywhere, but here they seemed in excess of any other place. The old Bahama channel was thoroughly sounded by the *Blake*, the least depth being abreast of Paradon light, 284 fathoms; 500 fathoms abreast Lobos Cay light (this depth was taken over a sounding marked on the chart 900 fathoms, no bottom). A great many soundings were taken between Jamaica and the southwest end of Haiti, the result being the development of a narrow channel connecting the waters of the main Caribbean with the waters north of Jamaica. This channel runs close to Haiti, with a greatest depth of 1,200 fathoms, the bottom temperature 39½°, and a general depth of 1,000 fathoms. The bottom everywhere was ooze. South of Navassa we found a large bed of the pteropod shells. The course of this channel is northerly along the western end of Haiti, where it does not exceed a width of five or six miles, thence westerly south of Navassa island, with a tongue to the northward and another to the westward between Formigas bank and Jamaica. We were here in the latter part of January, spending some ten days. We always found the current setting to the eastward, from one-half to one knot per hour. We met the English squadron at Port Royal, and I examined the logs of various vessels ; all had found the same current setting to the eastward as far as the Mona passage. Jamaica was connected by soundings and serial temperatures with the Mosquito coast *via* the Pedro and Rosalind banks. The depths between Jamaica and the Pedro bank were : from Jamaica, 322, 320, 293, 236, 381 and 447 fathoms, the temperature of the latter sounding being 44½°. My map was too small to draw the 500 fathoms curve, but the water to a depth of 600 fathoms makes in well to the westward, south of Jamaica. We spent eight days under the lee of N. E. Cay waiting for a lull in the trades to do the next channel; but it did not come, and we returned to Kingston, remaining there two weeks. Two lines only were run between the Pedro and Rosalind banks. The depths across were : 440, 675, 733, 642, 688, 609, 561, 478, 435 and 264 fathoms. The lowest bottom temperature was at 733 fathoms, 40°, the others all above 40°. I think it very probable that there is less water to the eastward of where we ran our lines. There was a little more than 200 fathoms in the narrow passage west of the Rosalind bank.

The bottom in the channels was very fine coral sand, not the smooth bottom found where there was a strong current. The current during February, March and April did not seem to be setting to the westward through these channels, except in the very narrow one west of the Rosalind bank. Several captains of vessels reported a northerly current to the eastward of these banks. To the eastward of Portland Rock, the eastern extreme of the Pedro bank, we found a very strong easterly current in the latter part of February, the trades blowing a gale at the time.

A line of soundings was run from Santiago de Cuba to the east end of Jamaica, and a depth of 3,000 fathoms was found 25 miles south of Cuba. Subsequent soundings proved this spot to be the eastern end of an immense deep valley extending from between Cuba and Jamaica to the westward, south of the Cayman Islands as far as the Bay of Honduras.

The Cayman Islands and the Misteriosa bank were found to be a submarine extension (very steep on its southern slope) of the range running along the southeastern side of Cuba. The valley is narrow at its eastern end, but widens between the western end of Jamaica and Cape Cruz, where the soundings were 3,000 fathoms within 15 miles of Cuba, and 2,800 fathoms within 25 miles of Jamaica. This valley is 700 miles long, with an average breadth of 80 miles. It covers an area of over 85,000 square miles, having a depth nowhere less than 2,000 fathoms, except at two or three points which are the summits of submarine mountains, and with the greatest depth of 3,428 fathoms. The low island of Grand Cayman, which stands scarcely 20 feet out of the sea, is really the summit of a mountain 20,568 feet above the bottom of this submarine valley, an altitude exceeding that of any mountain on the North American continent. Between Misteriosa bank and Chinchorro bank the soundings were regular at 2,500 fathoms. North of Misteriosa and Grand Cayman to the Isle of Pines and Cape St. Antonio, the soundings were generally 2,500 fathoms. The bottom everywhere in the western Caribbean is pteropod ooze, with a slight mixture of coral sand, which has been brought by the wind and water from the islands and keys.

A wide band of westerly current was found south of the Caymans and the Misteriosa bank, turning to the northward at Chinchorro bank, and so following the coast to the Yucatan passage. There was a narrow stream joining this main current from a passage between the Rosalind bank and the Mosquito coast, but I did not detect any flow from the other passages. North of the Caymans we found very little, if any, current. There is said to be a current which sets strongly to the eastward south of Cape St. Antonio.

Thus I have given you a summary of the data obtained by the *Blake* in as brief a form as possible.

The development of the ridges connecting the islands and the deep valley in the western Caribbean sea are certainly very interesting, considered as physical features, and I think that the temperatures obtained at different depths, especially on the ridge at the Windward passage, together with the currents observed, give us facts enough to lay out a possible course for the equatorial current from a point southeast of Barbadoes to the Yucatan passage. There is, certainly, a very large volume of water pouring through the Windward passage, flowing south of Cuba and so on to the Gulf of Mexico; and the temperatures of the water at different depths agree at the same season with those found in the Gulf of Mexico and the course of the Gulf Stream as I have laid it out.

Where does it get this temperature? It is not warmed in the Gulf of Mexico, for the latest theory is that it does *not* flow around this basin. Professor Hilgard, of the Coast Survey, has given a lecture quite recently before the Academy of Science, entitled "The Basin of the Gulf Stream," in which he shows that the current merely enters the passage at Yucatan to be forced by the head of water to the northward and westward out through the Florida straits. The currents in the Gulf are not connected with the Gulf Stream, and are very slow.

The temperature is several degrees higher at the same depth at the Windward passage than at the Barbadoes and from Trinidad to Guadaloupe. The comparison of these temperatures is made from observations taken at both places in the months of January and February.

The temperature below 800 fathoms in the western Caribbean and Gulf of Mexico could only enter over the rim at the Windward passage and between Haiti and Jamaica; but at the latter point there is no current setting that way; in fact, the pteropod shells showed an eddy.

I suggest that the water of the Gulf Stream is warmed in the main Caribbean, and that there is a possible current flowing around the entire boundary. The equatorial current striking against South America is deflected north, and when it reaches the island of Tobago all that can flow between this island and the main land and south of Grenada does so. This current is said to be felt along the Spanish

Main. The greater part of the equatorial current, however, is deflected north between Barbadoes and the Grenadines, finding its way to the westward whenever it meets a passage. Passing through, it would naturally be driven towards the Spanish Main by the trade winds, and thus bank up in the southwestern corner. While working between the islands south of Guadaloupe we were always well to windward during the night, and therefore felt the northerly set which I wrote of to Mr. Patterson, but north of Guadaloupe, in April, we had comparatively calm weather, and here the current came from the westward, and above Saba island was flowing as if to follow around the Virgin islands. After turning these, it would be helped along towards the Windward passage by the northeast trades.

As stated, the temperature to 400 fathoms suddenly increased, as we passed north of Guadaloupe. Could not this be accounted for by the equatorial current having made the circuit of the main Caribbean and been warmed on its passage over shoals and banks, after traveling nearly 3,000 miles ? The current said to flow along the Spanish Main would be deflected north by the Isthmus and keep on following inside, or to the eastward of the banks connecting Jamaica with the main land, and so south of St. Domingo, to pass out through the Mona passage and the Anegada passage, to flow along north of Porto Rico and St. Domingo to the Windward passage. We found a current in the latter part of April flowing north through the Mona passage and joining the current to the westward.

Of course we must have many more facts to substantiate any such theory as I have given. The temperature of the water at different depths must be observed to the eastward of the Anegada passage and over the main Caribbean; and these temperatures must be taken in the same season at the different localities.

I will not occupy your attention any longer here, but you can deduce your own theories from the facts given. The contour lines drawn on the map, with the exception of those along the coast of South America, are from the soundings of the *Blake*. The 100 fathoms curve, is from the United States and English surveys.

Last summer during several weeks the *Blake* was employed entirely on a dredging cruise, extending from a point off Charleston,

S. C., to the Georges banks. Professor Agassiz accompanied the vessel, and named localities for dredging and cared for the life obtained. We had dredged off Charleston in 100 fathoms, then in 200 fathoms. Mr. Agassiz wanted 400 fathoms for the next haul. We steamed to the eastward, but instead of finding deeper water it shoaled. The soundings across the stream were as follows: 142, 198, 225, 217, 236, 229, 258, 334, 382, 364, 337 fathoms.

The next point for dredging was off Cape Hatteras. To reach this point, I kept in the imaginary axis of the stream as marked on the chart, and sounded every five miles, with the following depths: 257, 291, 274, 288, 265, 262, 257, 247, 233, 246, 267, 288, 310, 338, 362, 400, 457, 892, 1,386, the above from lat. 32° 00′ N. to lat. 33° 30′ N.

These soundings were announced in the newspapers as the discovery of a plateau extending from the Carolinas to the Bahamas. This plateau was known at the Coast Survey office. Professor Bache spoke of it as long ago as 1856. He stated: " The discovery has been made that soundings can be carried nearly across the Charleston section of the Gulf Stream, and that after losing them on this section for a short distance, they were reached beyond the axis of the stream, as resulting from the observations of Lieutenants Maffit and Caven, U.S.N., Assistants in the Coast Survey." He says: " The bottom of the sea slopes gradually in this section for some 50 miles, reaching a depth of about 20 fathoms; then more rapidly to above 65 miles and the depth of 100 fathoms, and suddenly falling off to a depth *greater* than 600 fathoms; at about 100 miles from the shore, where the depth is 300 fathoms, a ridge with a very steep slope on the inshore side, and a little less to seaward, occuring 1,500 feet above the hollow to seaward of it, and distant about 12 miles from it. A second rise of 500 feet, on a base of 12 miles, followed by a depression of 300 feet on a base of 15 miles, and then by a gentle slope upwards. It is altogether probable that all the depths found by observation are greater than the actual ones, but the bottom was brought up in several cases, showing that the lead had reached it. It is most probable that the proportions are not far from correct."

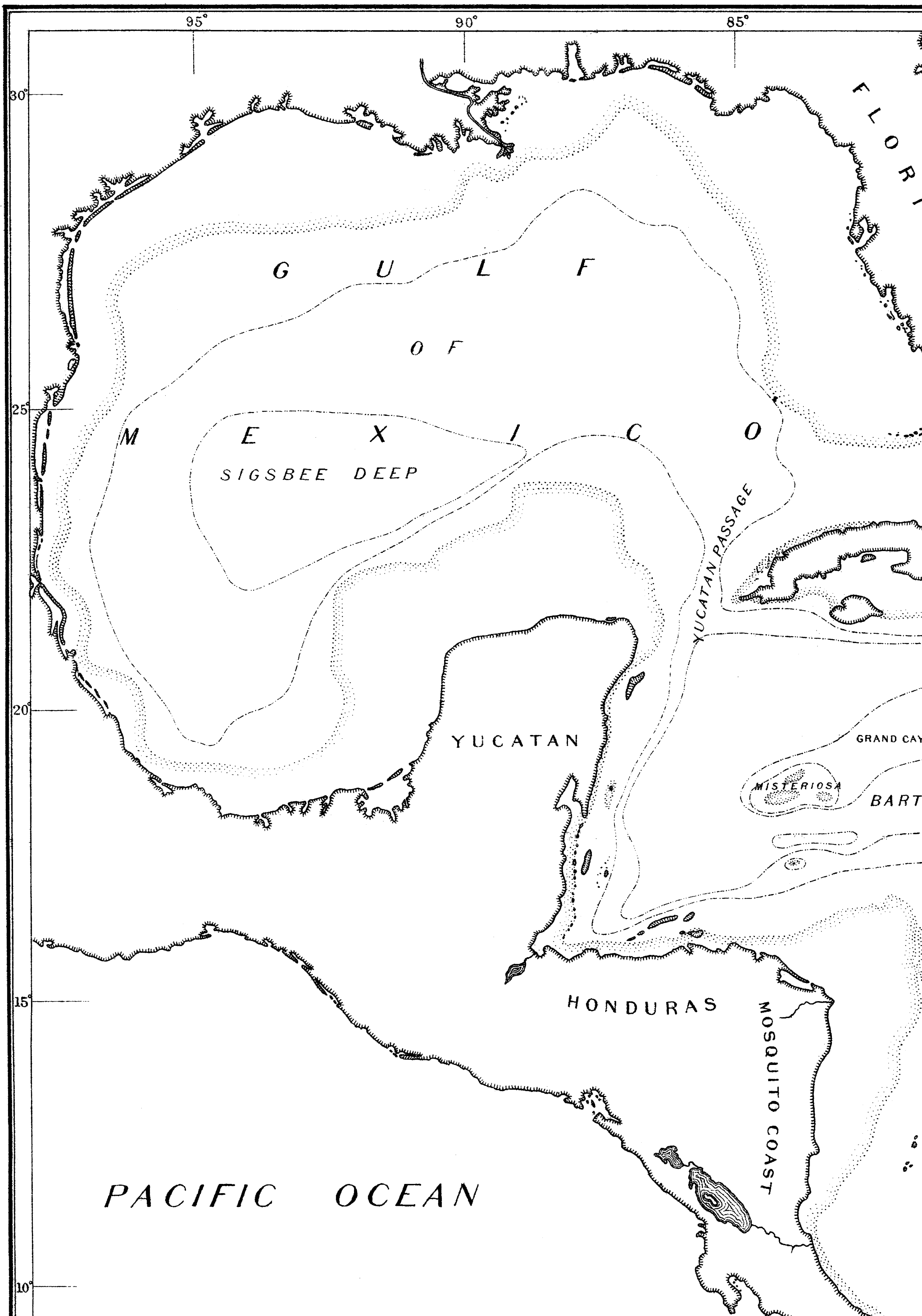
It will be seen how difficult it was to obtain the depth with the old methods. The soundings over this section were reduced one-half by the *Blake*, and at this rate the temperatures taken can hardly be relied upon. We were a little more than two minutes taking these soundings, and always brought up a specimen of the bottom. The temperatures that I find in the diagram of Prof. Bache are not as low as those of the *Blake*, although we had less water. The season was the same—in July. The temperature of 57° was found at 350 fathoms, and also at 600 fathoms, by Craven and Maffit. The thermometer probably never reached the bottom. We found a temperature of 45° to 46° from 300 to 380 fathoms. The bottom off Charleston was coarse grey sand, black specks, broken shells to 100 fathoms; then fine green sand and black specks, then came coral sand and broken shells and pteropod shells. As we came more into the stream, the bottom was washed bare, but the cylinder brought up small pieces of coral rock and coral sand. Mr. Agassiz has reported on the life obtained.

As we came north along the Gulf Stream and the water deepened, glob. ooze began to appear in the bottom specimens. The investigation of the Gulf Stream off Florida and as far as Hatteras, will be renewed by the *Blake* in the spring. The temperature of the water off the Georges bank in 300 fathoms was 40°. Other soundings and temperatures that we took last summer are interesting, but I must close my remarks, as I wish to speak of the methods of obtaining the results given you this evening. Some of my hearers have probably seen Lt.-Comdr. Sigsbee's very interesting and instructive book issued by the Coast Survey on deep sea soundings. I wish all interested in this subject could read it. Lt.-Comdr. Sigsbee was in command of the *Blake* for four years, and sounded the whole of the Gulf of Mexico, making the necessary examination into its physical conditions. Most of our apparatus was either invented by this officer, or are improvements on known methods.

The *Blake* is a small steamer of 320 tons, belonging to the Coast Survey. She is manned by eight officers and 38 men, and is fitted expressly for deep sea sounding and dredging. It has been my good fortune to have associated with me on this duty, officers who have rivalled me in their interest in the work. The great work done by the *Blake* bears testimony to their earnestness, and the records to their care and precision.

[The reading of the paper was followed by a description of the methods employed on board the *Blake* in obtaining depths, temperatures, etc. Models and drawings were shown of the different instruments.

A vote of thanks was tendered to Commander Bartlett for the reading of his paper before the Society, and a copy requested for publication.]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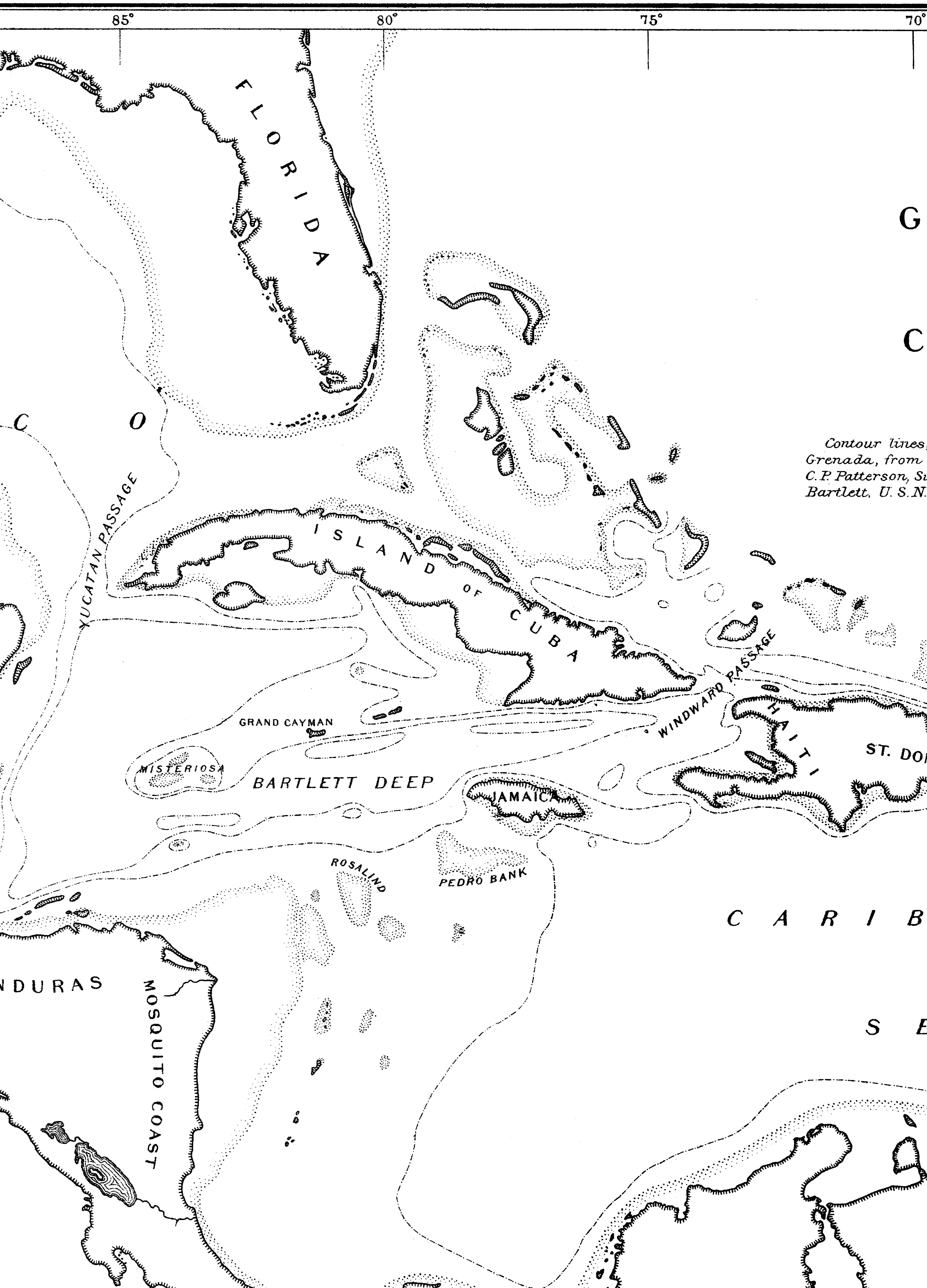


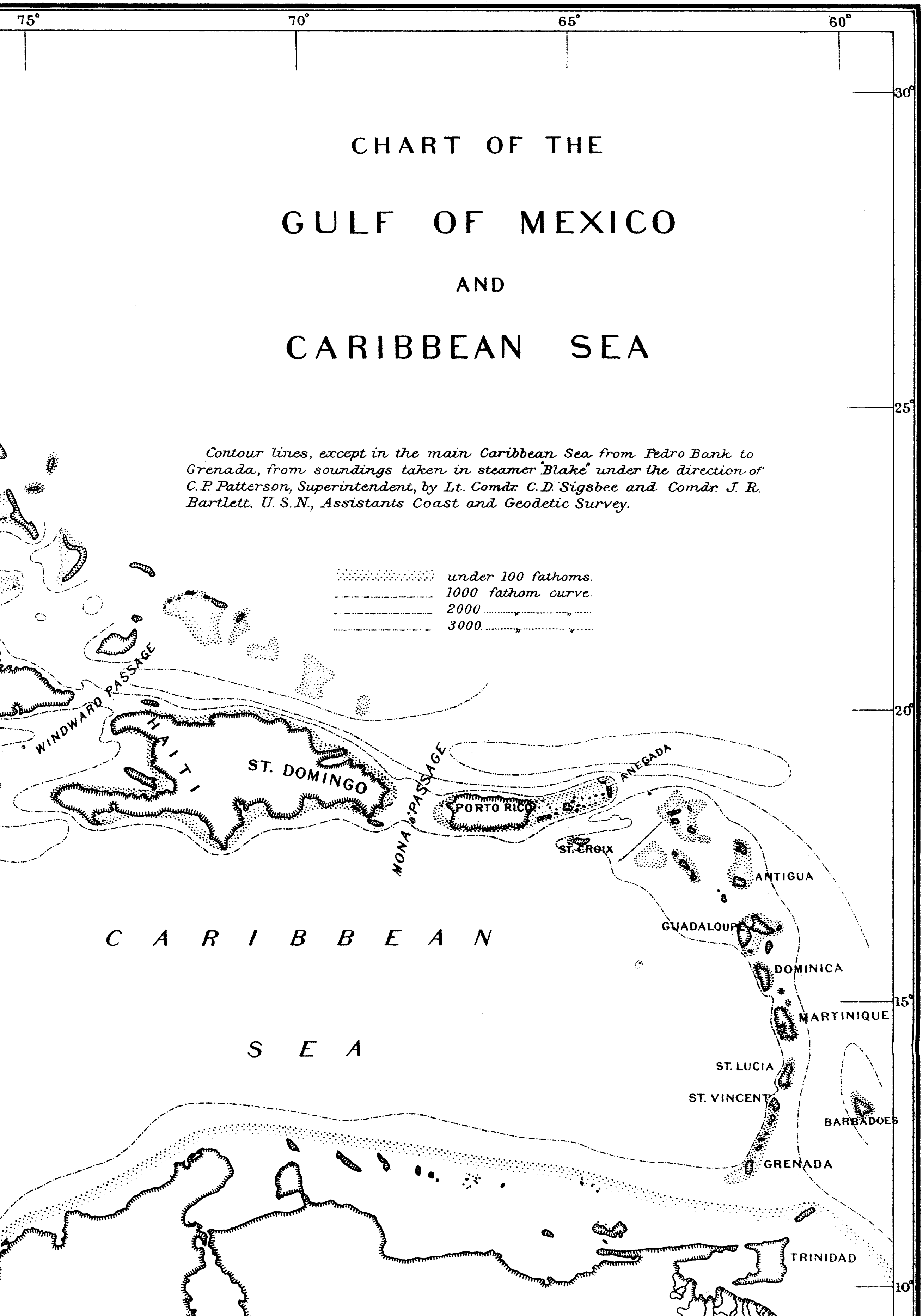


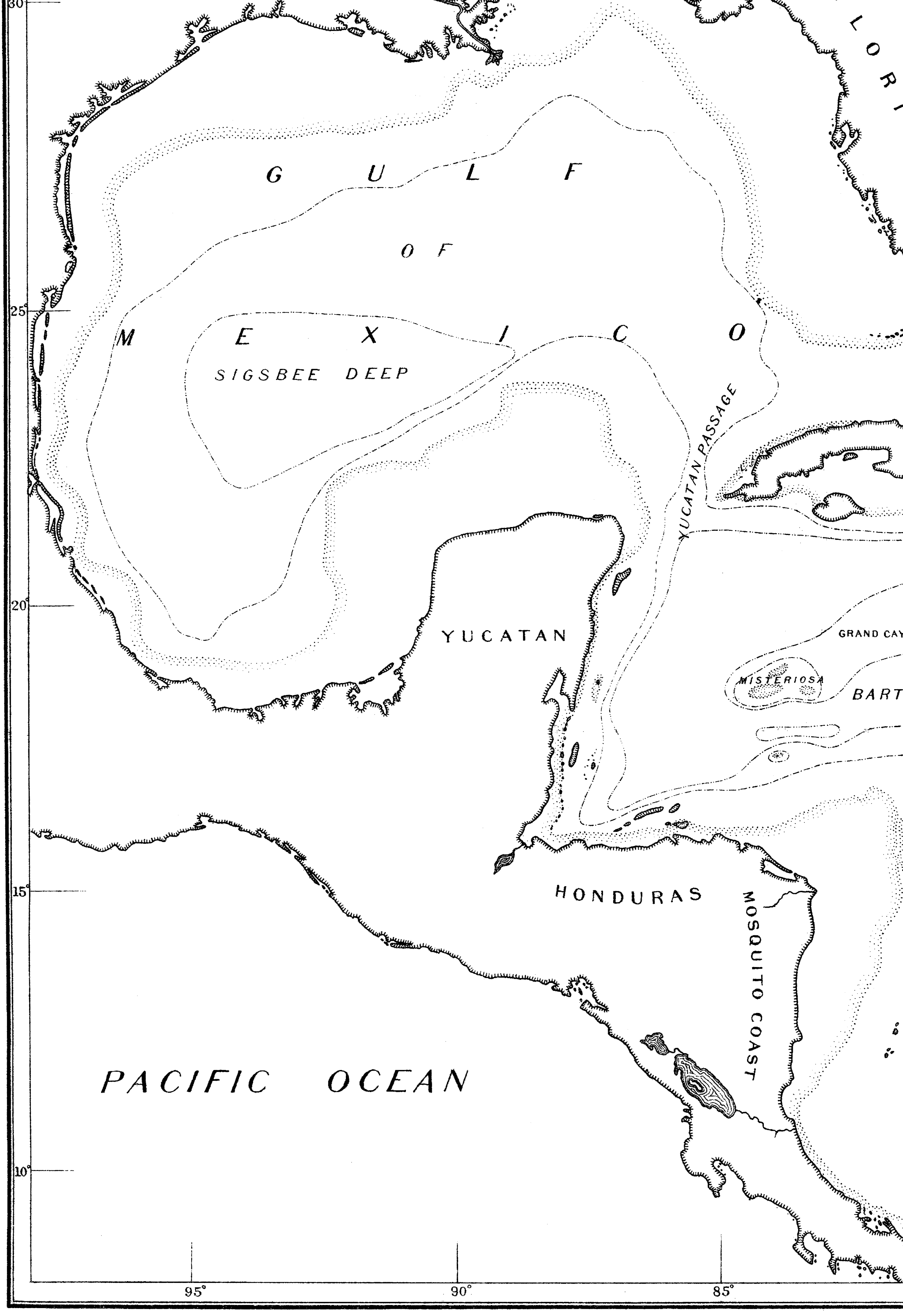
CHART OF THE

GULF OF MEXICO

AND

CARIBBEAN SEA

Contour lines, except in the main Caribbean Sea from Pedro Bank to Grenada, from soundings taken in steamer "Blake" under the direction of C. P. Patterson, Superintendent, by Lt. Comdr. C. D. Sigsbee and Comdr. J. R. Bartlett, U. S. N., Assistants Coast and Geodetic Survey.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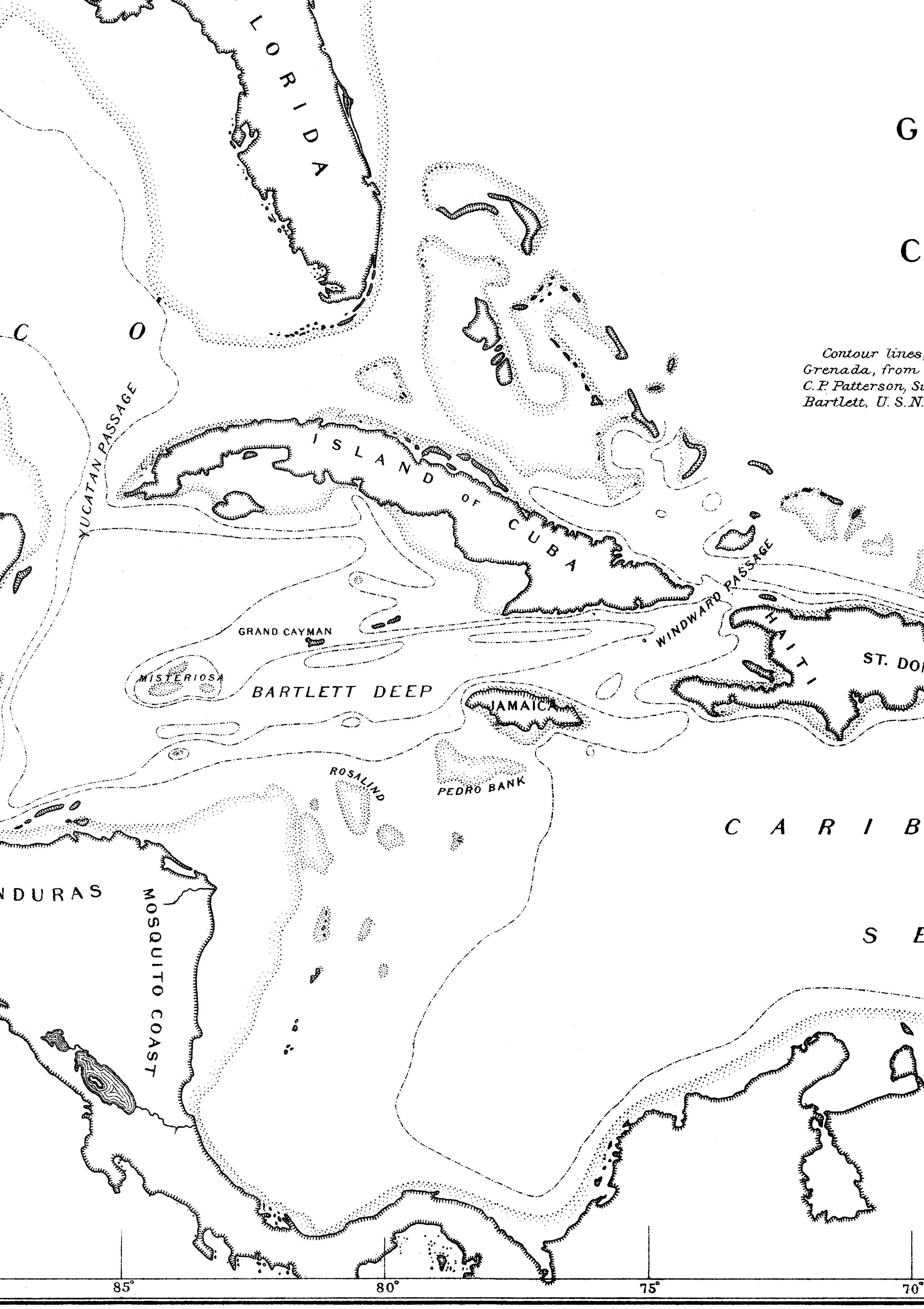
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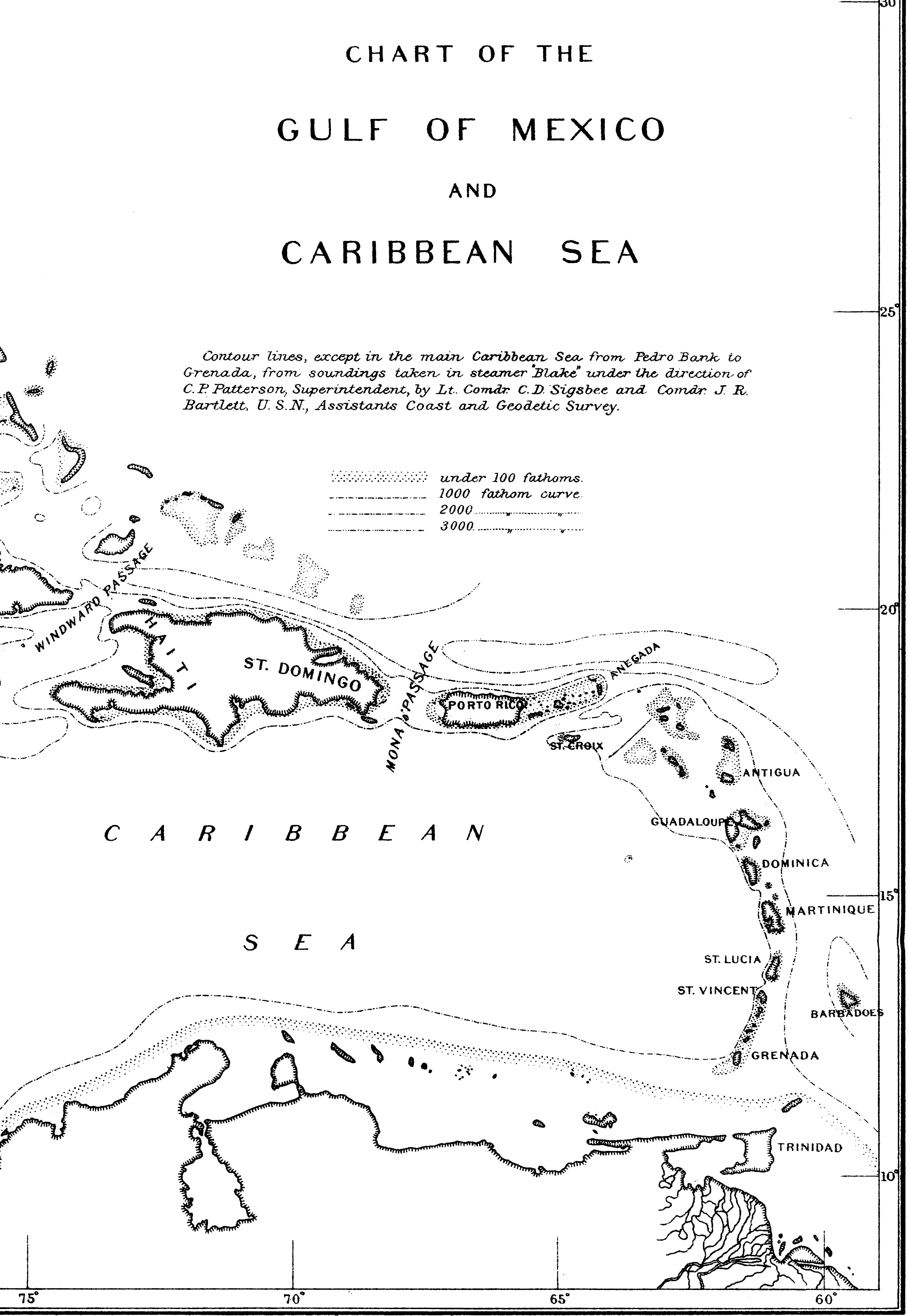

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